

Hand-Eye Dominance and Depth Perception Effects in Performance on a Basic Laparoscopic Skills Set

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ABSTRACT

Objectives: Our study determined whether depth perception defects and hand-eye dominance affect an individual's ability to perform laparoscopic skills.

Methods: The study cohort comprised 104 third-year medical students from LSU School of Medicine who completed a questionnaire including information on handedness and were tested for eye dominance and depth perception by using standardized methods. Training sessions involved an initial recorded performance, a 20-minute practice session, followed by a final recorded performance. Recorded sessions were randomized and rated by using a visual analog scale (maximal possible score = 16) based on overall performance (OPS) and depth perception (DPS). A general linear model was used to correlate depth perception defects and hand-eye dominance with assessment scores for OPS and DPS.

Results: Students with depth perception defects scored significantly lower on their initial performance than did those with normal depth perception (OPS, 4.80 vs. 7.16, $P=0.0008$; DPS, 5.25 vs. 6.93, $P=0.0195$). After training, the depth perception defect group continued to have lower scores compared with the normal depth perception group. However, the 2 groups showed similar increases in pre- to posttraining performance scores (OPS, 3.84 vs. 3.18, $P=0.0732$). Hand-eye dominance did not significantly affect scores.

Conclusions: Depth perception defects appear to compromise an individual's ability to perform basic laparoscopic skills. Individuals with defects can improve their

skills by a proportion comparable to that of people with uncompromised depth perception. Differences in hand-eye dominance do not correlate with performance differences in basic laparoscopic skills. Although further research is necessary, the findings indicate that training can be tailored for individuals with depth perception defects to improve laparoscopic performance.

Key Words: Laparoscopy, Hand-eye dominance, Minimally invasive surgery, Skills acquisition, Surgical education.

INTRODUCTION

The value of simulation training in laparoscopic basic skills surgical education has been demonstrated repeatedly.¹⁻⁴ Laparoscopic simulation trainers and skills education are now being integrated into resident and medical school curricula.⁵⁻⁷ They are used to train practicing physicians and are now used in high-stakes examinations for certifying practitioners in fundamental laparoscopic skills.^{8,9} Laparoscopic simulation exercises allow deliberate practice at convenient times and have even been demonstrated to increase surgical skills proficiency as a "preoperative warm-up."¹⁰ Several exercises that mimic fundamental tasks have been validated and the effects of their repetitive performance measured.^{1,2,11} Laparoscopic simulators can be used to characterize trainees' learning curves for basic skills and assist in identifying individuals who may require additional training to achieve mastery in them.¹²

Mastery of laparoscopy is difficult, requiring practice and a certain amount of innate psychomotor skills. One major challenge in laparoscopy is the translation of a 2-dimensional image of the operating field into a 3-dimensional mental image. Not only must the surgeon learn to operate using long instruments, he or she must also adapt to the optical constraints of the video screen. Individual differences in visual adaptation to the laparoscopic environment may play a role in the acquisition of laparoscopic skills. Few studies have investigated visual perception and visual depth cues in relation to performance of laparo-

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scopic procedures. For example, Shah et al¹³ demonstrated that visual depth cue reliance also differs between novices and experienced performers. The true relationship between depth perception and laparoscopic basic skill acquisition, however, has not yet been established.

Traits like handedness and hand-eye dominance may play a role in laparoscopic performance. Although traditional open surgical techniques tend to favor the right-hand dominant surgeon, laparoscopy requires the ability to use both hands equally well.¹⁴ Results linking handedness and laparoscopic performance are conflicting. For instance, Grantcharov et al¹⁵ have shown that right-hand dominant individuals have fewer excess movements and trend towards better results as measured by time and errors when performing the MISTELS simulator program. Conversely, results from Powers et al¹⁶ show better initial performance from left-handed surgeons but similar postsimulation curriculum performance for both right- and left-handed surgeons. Hand-eye dominance has been studied extensively in relation to performance in athletics. For example, studies of rifle marksmanship show that crossed hand-eye dominant individuals do not learn marksmanship skills as readily as individuals with matched hand-eye dominance do.¹⁷ Initial investigations in endoscopic surgical teaching show that optometric qualities, such as crossed eye-hand dominance, may correlate with laparoscopic skill.⁸ The present study investigates both depth perception and hand-eye dominance in relation to novice performance of basic laparoscopic skills on inanimate simulator trainers.

MATERIALS AND METHODS

From September 2006 to January 2008, 104 third-year medical students from the Louisiana State University (LSU) School of Medicine completed one Minimally Invasive Surgical Simulation Training (MISST) training session. The session consisted of 3 training exercises including a 2-handed peg transfer task, a 1-handed peg transfer task, and a forward and backward key threading task. The skills were designed to improve hand-eye coordination in the use of laparoscopic instruments.

Before training, students completed a questionnaire that documented visual defects; corrective eye surgery; and prior laparoscopic, simulator, and video game experience. The data form also documented handedness, which was noted by self-report, and eye dominance, which was tested using the single-eye technique where a distant object is viewed through a closed circle while each eye is closed alternately. Depth perception status was tested by using the graded circle test (Stereo Optical Co., Inc., Chi-

cago, IL) The test consists of 9 diamonds, each with 4 circles within the diamond. Students were instructed to wear polarized viewers and to pick which circle within the diamond appears closer to them. Each of the 9 items correlates with a certain degree of arc (ie, from 40 to 800 seconds). A perfect score of 9 correlates with the ability to differentiate 40 seconds of arc. Scores of ≤ 7 correlate with ≥ 60 seconds of arc and indicate a degree of defective depth perception.

The training format was similar for every participant. Students first watched an introductory video explaining how each task should be performed. They then video recorded an untutored performance of the first task after which they were given 20 minutes to practice the task. During this time, they received standardized instruction via video-based, text-based, or faculty-tutored methods. Upon completion of the practice session, students then video recorded a final untutored performance of the task. This same cycle was repeated for the remaining 2 tasks. The order of tasks was the same for all participants: 1) 2-handed peg transfer, 2) 1-handed peg transfer, and 3) key threading.

After collecting all data, all videotapes were compiled and edited to remove personal identification information. We used the first peg transfer exercise, which has been previously validated, for the results of this study.^{1,2,8,9,11} These video recordings were then reviewed by 4 independent raters on the basis of an overall performance scale and a depth perception scale. This scale was developed by faculty at LSU Health Sciences Center and consisted of a behaviorally anchored visual analog scale using a continuous measurement ranging from 0cm to 16cm. Variables used to rate overall performance included noting erratic jerking, unintentional movement, over/under grasping, knocking of pegs, or drops. Variables noted in the assessment of depth perception included pointing past object (over grasping), grasping before object (under grasping), and depth adjustments. Scores in both of these categories were measured in centimeters to the nearest tenth. All raters underwent training on the measurement scale by using sample videos. Inter-rater reliability was evaluated by the intraclass correlation coefficient (ICC), which assures the reliability.

The data in the questionnaire and assessment results of the videos were compiled and matched. Descriptive statistics (mean and standard deviation) were calculated for visual defects (VD), depth perception defects (DPD), and hand-eye dominance. The relationships between VD, DPD, and hand-eye dominance were examined by com-

puting the Cochran-Mantel-Haenszel statistic (CMH). A general linear model was used to examine the relationship between these variables and the assessment scores of the Overall Performance Scale (OPS) and the Depth Perception Scale (DPS). In addition, descriptive statistics (ie, mean and standard deviation) were calculated for the OPS and DPS scores. SAS 9.1 was used to perform the statistical analysis.

RESULTS

Of the 104 students completing the training, 13 were excluded from analysis because of mismatched identification information or missing data. As shown in **Table 1**, among the 91 students included in the analysis sample, 52.7% had myopia or another visual defect, 15.4% had a depth-perception defect, and 38.5% were cross-eye dominant. No significant correlation was found between these physical characteristics (CMH=0.88, $P=0.48$).

Table 1.

Physical Characteristics of MISST Program Participants

Characteristics	Frequency	Percentage
Handedness		
Right	85	93.4
Left	6	6.6
Eye dominance test		
Right	54	59.3
Left	37	40.6
Visual defects		
No defect	43	47.3
Myopia	30	33.0
Myopia and other	12	13.2
Other*	6	6.6
Hand/Eye dominance		
Same-eye dominance	56	61.5
Cross-eye dominance	35	38.5
Depth Perception defect†		
Yes	14	15.4
No	77	84.6

*Other visual defects include astigmatism, hyperopia, presbyopia, anisometropia, loss of vision in one eye.

†Depth perception test score ≤ 7 .

The 4 video reviewers/raters achieved a very good inter-rater reliability measured by ICC. For the OPS, the ICC was 0.82, and for the DPS, the ICC was 0.84. Given this high level of reliability, the mean of the 4 raters' scores was used as a final assessment score for each scale. The mean and standard deviations of the OPS and DPS for hand-eye dominance, and depth perception defects are displayed in **Tables 2** and **3**, respectively.

Scores in the hand-eye dominance assessment showed that differences in hand-eye dominance (ie, cross-eye dominance) did not affect performance in the simulator exercise. Pre- and posttraining scores for both the OPS and DPS scales were similar for both same-eye dominant and cross-eye dominant participants.

Statistically significant differences existed, however, between the presence or absence of depth perception defects and students' performance scores. As shown in **Table 3**, students who had depth-perception defects were rated significantly lower than those with unimpaired depth perception in pretraining trials for both scales (OPS, $P=0.0008$; DPS, $P=0.0195$). After training, DPD students' scores were still lower overall than scores for the normal group. However, the mean gain scores from pre- to post-training for each group was similar (OPS, $P=0.0846$; DPS, $P=0.0732$), indicating that the DPD students had a similar benefit from the learning experience as those of students with normal depth perception.

DISCUSSION

The study population consisted of 91 third-year medical students who were novice performers with limited exposure to laparoscopy and laparoscopic simulators. The intention of the study was to characterize the learning process of laparoscopy. We intended to investigate factors that predispose individuals to differ in initial performance of laparoscopic simulator exercises and personal characteristics that can aid or hamper the learning process. While studies in the past have focused on handedness, visual spatial perception, sex, and previous experience, none to date have focused on depth perception and depth perception defects.

Depth perception is inherently reduced in laparoscopy.¹⁹ In open surgical techniques, binocular vision is used, and retinal disparity creates a stereo image that provides a surgeon with a strong sense of depth. In laparoscopy, the operative field is translated into a 2-dimensional image on the monitor. Some 3-dimensional cues are lost, while monocular cues, such as overlap, lighting, and outline, are

Table 2.
Effect of Hand/Eye Dominance on Video Rating Scores

	Video Rating Score					
	Overall Performance Scale			Depth Perception Scale		
	Pre [*]	Post [†]	Diff	Pre [‡]	Post [§]	Diff
With Cross-eye Dominance Yes (n=35)	6.49/2.85 [¶]	9.76/2.27	3.27	6.41/2.97	9.70/2.53	3.29
Without Cross-eye dominance No (n=56)	7.00/2.36	10.28/2.17	3.28	6.84/2.56	10.22/2.12	3.38

^{*}Cross-eye dominance does not affect pretraining OPS score (P=0.42).

[†]Cross-eye dominance does not affect posttraining OPS score after adjusted for pretraining score (P=0.43).

[‡]Cross-eye dominance does not affect pretraining DPS score (P=0.58).

[§]Cross-eye dominance does not affect posttraining DPS score after adjusted for pretraining score (P=0.42).

[¶]Mean/SD.

Table 3.
Effect of Depth Perception Defect and Video Rating Scores

	Video Rating Score					
	Overall Performance Scale			Depth Perception Scale		
	Pre [*]	Post [†]	Diff	Pre [‡]	Post [§]	Diff
With Depth Perception Defect (n=14)	4.80/2.16 [¶]	8.64/2.35	3.84	5.25/2.47	8.78/2.68	3.53
Without Depth Perception Defect (n=77)	7.16/2.47	10.34/2.10	3.18	6.93/2.56	10.25/2.15	3.32

^{*}Pretraining OPS score is significantly different between DPD and normal individuals (P=0.0008).

[†]There is no difference between DPD and normal individual in terms of posttraining OPS score after adjusted for pretraining score (P=0.0846).

[‡]Pretraining DPS score is significantly different between DPD and normal individuals (P=0.0195).

[§]There is no difference between DPD and normal individual in terms of posttraining DPS score after adjusted for pretraining score (P=0.0732).

[¶]Mean/SD.

used by surgeons adapting to the 2-dimensional environment. Shah et al¹³ have demonstrated that experienced surgeons use different cues than novices. This discrepancy may be due to the formation of different neuronal circuits created during the process of achieving expertise in laparoscopy. As a result, whereas seasoned surgeons use their experience to rely on certain subtle cues, novice performers tend to rely on more basic cues.

For this study, we hypothesized that, given the inherent reduction of depth perception in laparoscopy, novices with additional weaknesses in depth perception should initially perform worse on basic laparoscopic tasks than novices with normal depth perception, because these DPD novices would be at a psychomotor disadvantage due to their defects. By testing depth perception, we were

able to correlate essential depth perception weakness with performance of a basic laparoscopic skill. Interestingly, DPD students and those with normal depth perception all demonstrated similar gains in pre- to posttraining scores, suggesting that the learning process was equally effective for both groups. DPD students, therefore, are able to learn basic laparoscopic skills at a rate similar to that of non-DPD students, but they start out at a lower skills performance point. What remains to be studied is whether both groups can achieve the same skill levels with further experience and whether this translates into equal performance in actual surgical procedures.

When reviewing hand dominance in general, Powers et al¹⁶ have demonstrated that a basic skills curriculum in laparoscopy can improve performance in both left- and

right-handed surgeons. Using the McGill Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTELS), they showed that, although left-hand dominant surgeons showed better initial performance, no statistically significant difference was found between left- and right-handed surgeons on posttraining scoring. This initial better performance prior to training by left-handed individuals may be because left-handed individuals are more accustomed to using both hands and may have better facility with using the nondominant hand. Grantcharov et al,¹⁵ however, showed that right-hand dominant individuals had a decreased number of unnecessary movements and trended towards better results in terms of time and errors. Their study is consistent with results from Hanna et al²⁰ who showed that for novice laparoscopists, right-handed individuals had better first time accuracy and made fewer errors than left-handed performers did. These conflicting results show that hand dominance per se may not play a role in laparoscopic performance. To further investigate, we linked hand dominance with eye dominance. Studies focusing on hand-eye dominance have mainly come from research in athletics where superior performance has been linked to relationships between eye dominance and hand preference. For instance, Jones et al¹⁷ have shown that crossed-eye dominance hurts an individual's ability to learn rifle marksmanship. Similarly, research on novice golfers has demonstrated the importance of avoiding cross-eye dominance when putting. Golf putting in right-eyed novice golfers was better when the right-handed stance was used, while left-eyed novice golfers performed better using the left-handed stance.²¹ This effect may be purely positional or may be the result of faster processing of information from the dominant eye, leading to more accurate performance.²² Interestingly, the type of sport/activity appears to play a role in whether same- or cross-eye dominance is more beneficial. For example, a study on highly skilled basketball players from Spain suggests that cross-eye dominance may be an advantage in basketball.²³ Like the psychomotor skills used in athletics that require adaptation and coordination, laparoscopic skills may also be affected by hand-eye dominance.

The results of this study, however, indicate that differences in hand-eye dominance did not appear to alter the gain in performance of the 2-handed peg transfer task. The proportion of the participants demonstrating cross-eye dominance was consistent with percentages of cross-eye dominant individuals in the Robison et al²⁴ study of individuals with mental handicaps as well as the work of Classe et al²⁵ on baseball players. Students were novice

performers and therefore less likely to have adapted to the ambidexterity acquired by expert laparoscopists. Perhaps the 2-dimensional nature of the screen in laparoscopy negates the effects of crossed dominance because the primary cues used to establish depth on the screen are monocular cues. Nevertheless, further investigation is needed to characterize this relationship further.

The strengths of this study include the stability and uniformity of testing. A single faculty member led all sessions and conducted them in a strict and consistent manner. All students were prepared in the same way and were given the same amount of time to practice. Testing of depth perception and eye dominance were also done using the same methods and therefore ensured consistency as well. The methods used to test depth perception and eye dominance are a reliable and standardized means of determining each, respectively.

This study was limited in its use of only one validated task to evaluate performance. With further research, we can expand the scope of this experiment to include suturing and cutting tasks.

CONCLUSION

Depth perception defects appear to compromise novices' ability to perform basic laparoscopic skills. Through laparoscopic simulator training, individuals with depth-perception defects can improve these basic skills by a proportion that is comparable to that of people with no defects. Cross-eye dominance, however, is not an indicator of better or worse performance on laparoscopic basic skills. Further research is necessary to determine the extent of the effects of depth perception defects on all aspects of laparoscopic skills. Longitudinal studies to follow the continued improvement and retention of skills in individuals with depth perception defects would be important to determine whether adaptation to visual cues is permanently learned.

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